Volumetric Simultaneous T1, T2, T2* and Proton Density Mapping in One Minute Using Interleaved Inversion Recovery SSFP and Multi Gradient Echo Imaging

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Introduction

The quantification of MR relaxation constants is essential for diverse applications, including tissue characterization (1), perfusion imaging (2), contrast agent (3) and oxygenation quantification (4), or the calculation of synthetic MR images with user-defined contrast (5). It has previously been shown (6,7) that inversion recovery steady state free precession (IR-SSFP) provides means to measure T1, T2 and proton density simultaneously in a very short scan time. However, the technique lacks a quantification of T2*, which is essential for a quantification of the BOLD effect or superparamagnetic contrast agents. Therefore, a fast volumetric, interleaved IR-SSFP and multi-gradient echo (MGRE) sequence has been implemented and tested in the present study. The scan time was one minute for a volumetric coverage of the brain including the simultaneous quantification of all relevant MR parameters (T1, T2, T2* and PD).

Methods

Experiments were performed on a 1.5T clinical MR scanner (Achieva, Philips Medical Systems) using a birdcage head coil. A multislice (M2D) IR-SSFP experiment was interleaved with a MGRE sequence as sketched in Fig. 1, and 10 slices were measured in an interleaved fashion in order to have the full initial magnetization (M_0, cf. Fig. 1) at the beginning of the IR-SSFP experiment. The following sequence parameters were used for the IR-SSFP portion of the sequence: Slice-selective adiabatic inversion pulse, SSFP acquisition with TR/TE=4.0/2.0ms, α=50°, partial Fourier acquisition (factor 0.625), measured resolution 1.1mm x 1.1 mm in-plane, slice thickness 8mm, slice gap 4mm. 10 phases over the inversion recovery signal evolution were measured (total length 3850ms). The following sequence parameters were used for the MGRE portion of the sequence: TR=35ms TE+ΔTE=1.98ms+n×3.36ms, n=10 echoes, α=20°. The measured resolution and FOV were identical to those of the IR-SSFP experiment. Quantitative T1, T2 and proton density (PD) maps were calculated from the IR-SSFP experiment using the measured apparent relaxation time, T1*, the ratio of the initial (M_0) and steady state (M_{SS}) magnetization, and the flip angle as described in more detail in Ref. 6. The T2* was obtained from a 2-parameter exponential fit to the MGRE data. First *in vivo* experiments were conducted in 5 volunteers. The total scan time was one minute.

Results

All volunteer experiments were successfully completed, and quantitative maps with high spatial resolution could be reconstructed from the volumetric data. Selected *in vivo* results are shown in Fig. 2. The first, second and third row show color coded maps (10 slices) of T1, T2 and T2*, respectively. Please note the individual color scales at the right margins. The proton density is shown as a grayscale image in the fourth row. T1, T2, T2* and PD measured in a user-defined ROI in the frontal lobe are summarized in Table 1 (mean ± SD).

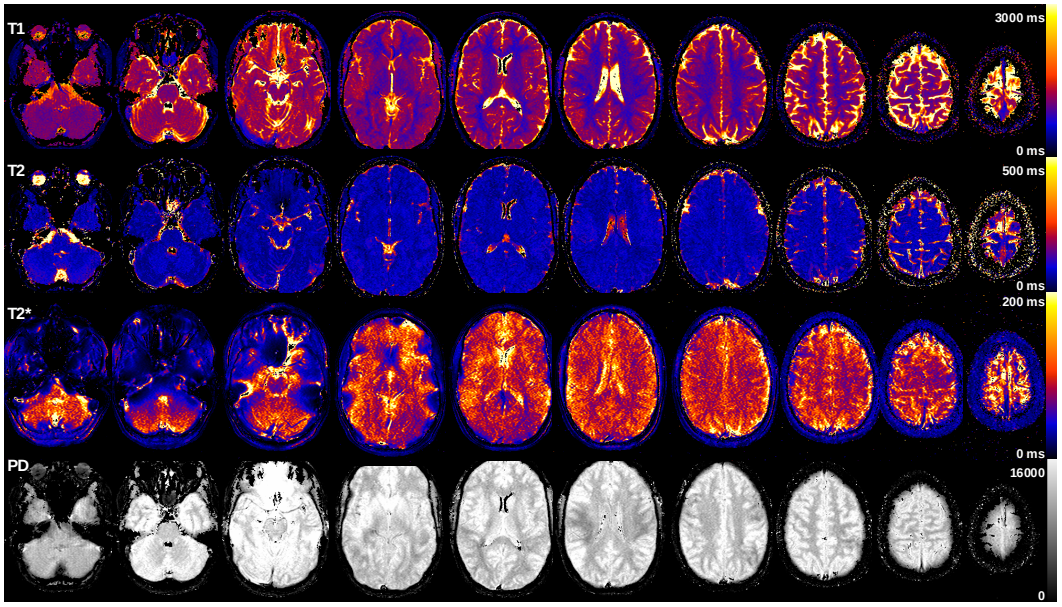

Fig 2. Volumetric *in vivo* data set with quantitative T1, T2, T2* and proton density (PD) maps

Fig 1. Schematic plot of interleaved inversion recovery SSFP and multi-gradient echo sequence. T1* denotes the measured T1, M0 and MSS denote the initial and the steady state magnetization, respectively.

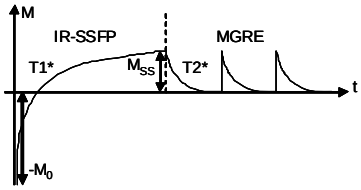

Table 1 . Measured T1, T2, T2* and proton density for different species (White matter, gray matter, CSF). All values are mean ± standard deviation over volunteer population

	T1	T2	T2*	PD
GM	1205 ms ± 48 ms	83 ms ± 11 ms	68 ms ± 16 ms	568 ms ± 67 ms
WM	815 ms ± 49 ms	67 ms ± 3 ms	52 ms ± 4 ms	542 ms ± 67 ms
CSF	2847 ms ± 166 ms	215 ms ± 66 ms	156 ms ± 69 ms	599 ms ± 77 ms

Conclusion

This study has shown that the present interleaved IR-SSFP and MGRE sequence provides promising means to acquire volumetric maps of the spatial distribution of all relevant MR parameters simultaneously and with good spatial resolution in as little as one minute. The measured values closely resemble previous results (6,7) and other literature values (8) where available. The present sequence allows for rapid quantitative MRI, and represents a fast localizer scan allowing for the generation of synthetic MR images with user-defined contrast.

References

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